

# MASTER OF SCIENCE IN MECHANICAL ENGINEERING

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## PROPAGATION OF FIRE GENERATED SMOKE IN SHIPBOARD SPACES WITH GEOMETRIC INTERFERENCES

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Master of Science in Mechanical Engineering-September 2000

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The propagation of fire generated smoke into a shipboard space with a geometric interference has been modeled using commercial software from the Computational Fluid Dynamics Research Corporation (CFDRC). This study was based on the dimensions of compartment 01-163-2-L and the installed ladder aboard an Arleigh Burke Class Flight IIIA Destroyer. A test model was run which validated the hindrance of fluid flow by a geometric interference. Smoke propagation scenarios were run in the shipboard compartment model. The results of the first scenario showed that smoke propagation is limited by the geometric interference. The results of the second scenario showed that smoke that is directed vertically is diverted by the geometric interference. The overall goal of this study is to show that computational fluid dynamics software can successfully model smoke propagation in shipboard spaces with a geometric interference.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation

**KEYWORDS:** Convection, Smoke Modeling, Computational Fluid Dynamics, Damage Control

## POSITION ESTIMATION FROM RANGE ONLY MEASUREMENTS

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In order for a team of several Automated Underwater Vehicles (AUVs), such as the ARIES, to operate cooperatively, operators require a cost effective position estimation method. Range only measurement (ROM) position estimation provides this and a means for the AUVs to identify each other's position. Position estimation usually requires at least two range measurements from known points to solve for a vessel's position. However, under certain conditions, one range only measurement can provide a simpler solution. This thesis proves ROM as a viable means of target tracking and position estimation. Determining the accuracy and observability of ROM serve as the primary focus. The ROM model setup and execution are discussed with specific attention given to the details of the Extended Kalman Filter (EKF) and calculations required to determine the system's observability.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Autonomous Underwater Vehicles, Unmanned Underwater Vehicles, Robotics, Navigation

### COMPUTATIONAL FLUID DYNAMICS PREDICTION OF SUBSONIC AXIS-SYMMETRIC AND TWO-DIMENSIONAL HEATED FREE TURBULENT AIR JETS

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A study was conducted to evaluate the accuracy of a commercial computational fluid dynamics (CFD) code (CFDRC-ACE+) for predicting incompressible air jet flows with simple geometries. Specifically, the axis-symmetric and two-dimensional heated air-jets were simulated using a standard  $k$ - $\epsilon$  turbulence model. These CFD predictions were directly compared to an extensive compilation of experimental data from archive literature. The round jet results indicated that the code over-predicted the velocity-spreading rate by 24% and the temperature-spreading rate by 29%. In addition, the centerline velocity and temperature decay rates were also over-predicted by 21% and 30%, respectively. The geometric and kinematic virtual origins were over-predicted, as well, by approximately 7.5 diameters for the velocity profiles and 10.5 diameters for the temperature profiles. The planar jet simulation was generally closer to experimental data ranges, with an under-prediction of the velocity-spreading rate of approximately 17% with an over-predicted temperature-spreading rate of 12%. The centerline velocity and temperature decay rates were both under-predicted at 22% and 27%, respectively. Again, the geometric and kinematic virtual origins were over-predicted by approximately 7.5 slot heights for the velocity profiles and 10.5 slot heights for the temperature profiles.

**DoD KEY TECHNOLOGY AREA:** Modeling and Simulation

**KEYWORDS:** Computational Fluid Dynamics (CFD), Eductor, Ejector, Gas Turbine, Exhaust, Axisymmetric Jet, Two-Dimensional Jet, Air Jet, Free Turbulent, Jet

### FREQUENCY RESPONSE ANALYSIS OF T-ACS EXPERIMENTAL DATA

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Master of Science in Mechanical Engineering-September 2000

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Trial runs of a 1:24 scale model crane ship were conducted in the David Taylor Model Basin. The model's response to regular waves under various ship configurations, crane configurations, sea states and ship headings relative to the incoming waves were recorded. The Response Amplitude Operator (RAO) Program analyzes the frequency responses to controlled, regular waves and generates full-scale RAOs as a prediction of the actual ships response. Accurate generation of these full-scale RAOs enables future prediction, using the principle of linear superposition, of ship motions in an irregular sea to be compared to actual, full-scale trial runs being conducted off the coast of California near Camp Pendleton in September 2000.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Power Spectral Density, PSD, Response Amplitude Operator, RAO

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## MECHANICAL ENGINEERING

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### **RANDOM WAVE ANALYSIS OF SHIP/RAMP/BARGE RESPONSE**

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A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, is developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. A standard second order model is used, for demonstration purposes, in order to model the frequency response properties of the connecting body.

Parametric studies of the response amplitude operator of the ramp motion are performed for varying wave directions and isolator stiffness and damping. These are utilized for the random wave analysis in standard fully developed seas. The results indicate that rational selection of isolator properties can result in significant reduction of motions and stress levels in the connecting ramp.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Isolator, Hydrodynamic Modeling, Roll On/Roll Off, Random Waves, Response Spectral Analysis

### **OSCILLATING FLOW ABOUT PERFORATED CYLINDERS**

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Circular cylinders of various sizes and perforations were subjected to sinusoidally-oscillating flow in a large U-shaped water tunnel. The force-transfer coefficients (drag and inertia) were determined in the range of Keulegan-Carpenter numbers (K) from about 1 to 40. The results have shown that the effect of the perforations is to decrease the inertia coefficient and to increase the drag coefficient. Thus, perforated cylinders are very efficient dampers and could be used in increasing the damping of cables and large structures in the ocean environment.

**DoD KEY TECHNOLOGY AREAS:** Sensors, Surface/Under Surface Vehicles - Ships and Watercraft

**KEYWORDS:** Oscillating Flow, Perforation, Cylinder, Damping, Cable, Marine Hydrodynamics

### **SIMULATION AND ANALYSIS OF PROGRESSIVE FLOODING IN A DDG 51 FLT IIA DESTROYER USING SIMSMART AND EXCEL SOFTWARE**

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Progressive flooding, if unchecked, can sink or mission kill even heavily compartmented naval ships. The designed watertight integrity and floodable length is negated by water intrusion into adjacent compartments through battle damage or material disrepair. This thesis uses a program set combining AHT Corporation's SIMSMART fluid flow analysis program with NPS-PF, a Microsoft Excel workbook, to analyze the effects of progressive flooding on the DDG 51 FLT IIA class of destroyers. The DDG 51 dewatering system is modeled using icons from the standard SIMSMART library, as well as USN-unique icons created in the course of this thesis. Multiple scenarios are run and analyzed simulating realistic progressive flooding due to gunfire, anti-ship missile hits and mine strikes. The program set is designed to enable total ship system engineers to model prototype ship designs and test their survivability in a wide range of realistic

progressive flooding scenarios. Simulation results would aid in the determination of compartmentation, bulkhead spacing, dewatering system capacity and quantity of portable dewatering equipment.

**DoD KEY TECHNOLOGY AREAS:** Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Flooding, Progressive Flooding, Fluid Flow Analysis, Naval Architecture, Ship Damage, Damage Stability, DDG 51, Excel, SIMSMART

### **EFFECT OF WATER DEPTH ON THE UNDERWATER WET WELDING OF FERRITIC STEELS USING AUSTENITIC Ni-BASED ALLOY ELECTRODES**

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**Master of Science in Mechanical Engineering-September 2000**

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Underwater welding using shielded metal arc welding (SMAW) on U.S. Naval Vessels is very attractive because of the ability to effect repairs without costly dry dock expenses. In the past the primary problems with underwater wet weldments on steels utilizing SMAW with ferritic electrodes, were underbead cracking in the heat affected zone (HAZ), slag inclusions, oxide inclusions, and porosity.

To avoid underbead cracking three weld samples were made using an austenitic nickel weld metal with an Oxytance coating at 10 feet of salt water, 25 feet of salt water, and 33 feet of salt water. A final sample was made using austenitic nickel weld metal with a Broco coating at 33 feet of salt water. Because of the ductility of the austenitic nickel weld metal no underbead cracking occurred, however porosity and high inclusion counts were found in all four samples. The average size of the inclusion increased with increasing depth. The Broco sample exhibited far greater porosity than did the Oxytance samples.

This work addresses quality of the welds, mechanisms for the formation of the inclusions, and analysis of the difference between the Oxytance and Broco weld rods.

**DoD KEY TECHNOLOGY AREA:** Materials, Processes, and Structures

**KEYWORDS:** Underwater Wet Welding, Non-Metallic Inclusions, Shielded Metal Arc Welding

### **REAL TIME COMPUTATION OF THE DELIVERY ACCURACY FOR AIR LAUNCHED UNGUIDED WEAPONS**

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**Master of Science in Mechanical Engineering-September 2000**

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In order to calculate the probability of damaging a ground target with air launched weapons, it is necessary to know the accuracy of the weapon that is used. At present, these accuracies are only tabulated for a few, specific delivery conditions. The thesis objective was to develop a methodology capable of generating real time delivery accuracy data estimated from user supplied release conditions.

The methodology was developed by studying the theory for accuracy measures, weapon delivery, and an error budget analysis. The accuracy measures include the desired mean point of impact, range error probable, deflection error probable, and the circular error probable. The weapon delivery includes the aircraft release maneuver, ballistic trajectory of unguided weapons, mode, and mechanization. The error budget analysis includes the derivation and explanation of 49 sensitivity equations that contribute to the delivery accuracy. The theory was implemented using Microsoft Excel and Visual Basic for Applications to compute the error budget and run a high fidelity trajectory program for the weapon delivery.

This real time data generation tool was developed as a component for future integration into the Joint Munitions Effectiveness Manual (JMEM) Air-to-Surface Weapon Engineering System (JAWS) and to provide a reference media for future work in the weapon engineering field.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Conventional Weapons, Modeling and Simulation

**KEYWORDS:** Delivery Accuracy, Weapon Accuracy, JMEM

### **APPLICATIONS OF ARBITRARY LAGRANGIAN EULERIAN ANALYSIS APPROACH TO UNDERWATER AND AIR EXPLOSION PROBLEMS**

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**Master of Science in Mechanical Engineering-September 2000**

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A series of underwater and air explosion investigations was conducted using the Arbitrary Lagrangian-Eulerian (ALE) numerical technique. The investigation primarily examined the explosive-fluid, fluid-structure, and fluid-air interaction effects, and the shock wave pressure propagation through a subjected medium, with the intent of verifying and validating the ALE analysis. The research also noted the explosive-air and air-structure interaction effects as well as shock wave pressure propagation effects. Three-dimensional underwater explosion analyses was conducted using TNT detonations. Two-dimensional air explosion analyses was completed using TNT detonations. With viable ALE results, underwater and air explosion modeling and simulation could become dependable, cost-effective, and time-efficient.

**DoD KEY TECHNOLOGY AREAS:** Conventional Weapons, Materials, Processes, and Structures, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

**KEYWORDS:** Underwater Explosion, Air Explosion, Arbitrary Lagrangian-Eulerian Analysis

### **PROPAGATION OF FIRE GENERATED SMOKE AND HEAT TRANSFER IN SHIPBOARD SPACES WITH A HEAT SOURCE**

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**B.S., Southern University and A&M College, 1992**

**Master of Science in Mechanical Engineering-September 2000**

**Advisor: Matthew D. Kelleher, Department of Mechanical Engineering**

The propagation of fire generated smoke and heat transfer into a shipboard space has been computationally modeled using a commercial code generated by Computational Fluid Dynamics Research Corporation (CFDRC). The space modeled was 1-158-1-L of an Arleigh Burke Class Flight IIA Destroyer. Three smoke and heat scenarios are applied to the space. For all three scenarios, the inlet used is the forward, inboard watertight door. Smoke enters the upper half of the door, while air enters through the bottom half. The temperature of the inlet fluids is altered to observe its effect on propagation. In the last scenario, the floor temperature is isothermally held at 1200 K to simulate a fire in the space below. The results of this scenario show that extreme temperatures of adjacent spaces has minimal effect on propagation. The overall goal of this study is to show how computational methods can be used to model propagation of smoke in shipboard spaces.

**DoD KEY TECHNOLOGY AREAS:** Computing and Software, Modeling and Simulation, Other (Damage Control)

**KEYWORDS:** Convection, Smoke Modeling, Computational Fluid Dynamics

